A power GARCH examination of the gold market

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Abstract

This paper investigates macroeconomic influences on gold using the asymmetric power GARCH model (APGARCH) of [Ding, Z., Granger, C.W.J., Engle, R.F, 1993. Long memory property of stock market returns and a new model. J. Empirical Finance 1, 83–106]. In this model the power term is estimated within the model rather than specified by the authors. This paper examines both cash and futures prices of gold and significant economic variables over the 1983–2003 period, with special focus on two periods, around the 1987 and 2001 equity market crashes. As specified in [Ding, Z., Granger, C.W.J., Engle, R.F., 1993. Long memory property of stock market returns and a new model. J. Empirical Finance 1, 83–106] a number of autoregressive conditional heteroskedasticity (ARCH) and GARCH models are nested within the APGARCH model. To estimate the goodness of fit of each model, likelihood ratio tests are used to assess the significance of each model and provide the best fit for the data. The results suggest that APGARCH model provides the most adequate description for the data, with the inclusion of a GARCH term, free power term and unrestricted leverage effect term. This paper is the first of its kind to undertake an APGARCH investigation of the gold price. The role of the dollar in gold is confirmed but few other macroeconomic variables have an impact.

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1. Introduction

The paper investigates the applicability of the asymmetric power GARCH model (APGARCH) introduced by Ding et al. (1993) and its nested variants to the gold market. In this model the power

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term is estimated within the model rather than specified by the authors. As specified in Ding et al. (1993) a number of ARCH and GARCH models are nested within the APGARCH model. To estimate the goodness of fit of each model, likelihood ratio tests are used to assess the significance of each model and provide the best fit for the data. The format for this paper is as follows; Section 2 begins with an introduction to the gold market, Section 3 consists of the consulted literature, Section 4 outlines the methodology used, Section 5 provides the results and Section 6 provides the conclusion to this research.

2. The gold market: an introduction

Gold is a precious metal which is also classed as a commodity and a monetary asset. It has acted as a multifaceted metal down through the centuries, possessing similar characteristics to money in that it acts as a store of wealth, medium of exchange and a unit of value (Goodman, 1956; Solt and Swanson, 1981). Gold has also played an important role as a precious metal with significant portfolio diversification properties (Ciner, 2001). Gold is used in industrial components, jewellery, as an investment asset and reserve asset. Gold is a unique asset in that much of the gold ever mined still exists today. Approximately 2500 tonnes of gold is mined per annum. Above-ground stocks account for 135,000 tonnes. Governments and investors account for approximately 60,000 tonnes, jewellery accounts for 63,000 tonnes and 15,000 tonnes is held in other forms such as electronics, etc. Gold is a highly liquid metal; it can be readily bought or sold 24 h a day, in large denominations and at narrow spreads. This is highlighted by Draper et al. (2006) who note that total annual production of gold is cleared by the London Bullion Market Association every 2.5 days.

While gold is an industrial metal, its uses are fewer compared to other metals, with only approximately 10% of gold demand derived from industry. Of perhaps more interest is gold’s use as an investible asset.

Central banks hold a large proportion of the above-ground stocks of gold (Kaufmann and Winters, 1989). Central banks and international financial institutions maintain 32,000 tonnes of gold in their reserve. Gold is held in central banks reserves for a number of reasons: diversification, economic security—gold maintains its purchasing power, physical security—gold is a liquid asset, confidence—cushion in a crisis, maintains value, income—gold leasing, insurance—against market crises. Much research also points to the benefits of inclusion of gold holdings as leading to a more balanced portfolio (Aggarwal and Soenen, 1988; Johnson and Soenen, 1997; Ciner, 2001; Egan and Peters, 2001; Sherman, 1982; Davidson et al., 2003; Draper et al., 2006).

3. Literature review

There are a number of assets, traced from the literature in this area, that have an influence on the gold market. In the 2004 period as the dollar weakened, gold reached a 16-year high (compounded also by uncertain economic conditions, geopolitical tensions and producer de-hedging). Further dollar depreciation and a growing risk of dollar devaluation are likely to strengthen investor demand for gold. Gold reflects the relative strength of the currency in which it is quoted. For example, the dollar price of gold may increase more in percentage terms than the sterling price of gold; the price change merely reflects the dollar weakness against sterling, rather than an intrinsic change in gold market fundamentals (World Gold Council, 2002). The depreciation in the dollar may fuel increased interest in gold due to the dilution in the dollar’s worth. Gold appears to be the anti-dollar. Financial analysts have attributed the rise in gold’s price in
recent months to the US dollar’s decline; gold is reflecting the US dollar’s value on international markets. A lower US dollar makes it less expensive for Europeans (and others) to buy dollar denominated gold. The weak dollar increases gold’s attraction as a stable place to invest money.

On examination of the literature, it is surprising to report that little research has been carried out on information transmission to the gold market. There are two recent papers in this area; the first is an examination of macroeconomic news releases on gold and silver prices by Christie-David et al. (2000) and the second a paper by Cai et al. (2001), both using gold futures intra-day data. Christie-David et al. (2000) examined the effects of monthly macroeconomic news releases on gold and silver future markets over the period 1992–1995 using intra-day data. This was analysed in conjunction with treasury and municipal bonds. Interest rates results are used as a basis of comparison. According to the authors this study “examines whether gold and silver prices relate to economic fundamentals . . . assist market participants manage risk and help build diversified portfolios” Christie-David et al. (2000, p. 406). Gold responds strongly to CPI news announcements, in addition to the unemployment rate, GDP and PPI. Gold future prices responded strongly to the release of capacity utilization information. Gold does not respond strongly to federal deficit announcements. According to Cai et al. (2001), who undertook an analysis of the effect of 23 macroeconomic announcements on the gold market, the market is impacted by employment reports, GDP, CPI and personal income. Using a high frequency dataset, Cai et al. (2001) found that on examination the 25 largest 5 min absolute returns during the period under investigation that the largest returns were due to the following occurrences: central bank sales, interest rates, oil prices, inflation rates, US unemployment rates, Asian financial crisis, concerns about consumer demand for gold and political tension in South Africa.

In previous research Tandon and Urich (1987) found that unanticipated components of US money supply and PPI announcements had significant impacts on the daily gold price. Bailey (1988) reported that unanticipated weekly growth in the announced level of money supply led to an increase in gold volatility. Kitchen (1996) investigated the effects of domestic and international financial variables to announced changes in federal deficit projections. Over the period 1981–1994 the author found that the price of gold responded positively and significantly to announced changes in federal deficit projections.

A number of authors have reported on the role gold plays as an inflation hedge and the role inflation plays on the gold price. According to Lawrence (2003), no significant correlations exist between returns on gold and changes in certain macroeconomic variables such as inflation, GDP and interest rates. Sjaastad and Scacciavillani (1996) reported that gold is a store of value against inflation. Baker and Van-Tassel (1985) documents that the price of gold depends on the future inflation rate. Sherman (1983) noted the log of the gold price is positively related to anticipated and unanticipated inflation. According to Kaufmann and Winters (1989) the price of gold is based on, as well as other variables, changes in the US rate of inflation.

Traditionally gold has played a significant role during times of political and economic crises and during equity market crashes; whereby gold has responded with higher prices. According to Smith (2002, p. 1), “when the economic environment becomes more uncertain attention turns to investing in gold as a safe haven.” The author notes that following the September 11th, 2001 terrorist attack, the FTSE All Share Index decreased by 9% while the London gold afternoon fixing price increased by 7.45%. Lawrence (2003) reported that gold returns are less correlated with returns on equity and bond indices than returns of other commodities. In line with gold’s role as an asset of last resort, Koutsoyiannis (1983) states that the price of gold is strongly related to the state of the US economy and geopolitical factors. Cai et al. (2001) noted that the
Asian financial crisis and political tension in South Africa, which is also reported by Melvin and Sultan (1990), are significant factors influencing the price of gold.

The importance of interest rates has been reported by a number of authors. Koutsoyiannis (1983) reported that the price of gold was strongly related to the US interest rate. Diba and Grossman (1984) found a close correspondence between the time series properties of the relative price of gold and the TS properties of real interest rates. Fortune (1987) also reported the significance of interest rates on the price of gold; increases in expected interest rates will cause a negative adjustment in the price of gold. In recent years, as reported in Cai et al. (2001) gold price changes are due to, among the other variables mentioned, fluctuations in interest rates.

The importance of oil prices on the price of gold is noted in the literature by Cai et al. (2001) and Melvin and Sultan (1990). According to Melvin and Sultan, political unrest in South Africa in addition to oil price volatility are significant factors that constitute the gold spot price forecast errors.

Baker and Van-Tassel (1985) in an examination of the monthly change in gold price over the period 1973–1984 found that changes in the price of gold are primarily derived from US variables, changes in US prices and changes in the value of the dollar. Similarly, Sjaastad and Scacciaillanni (1996) found that the gold market was influenced by the dollar. Numerous other studies have confirmed the influence of the dollar on the price of gold. Ghosh et al. (2000) reported that short run movements in the price of gold are influenced by the US/World Exchange Rate. Sherman (1983) stated that the log of the gold price was negatively related to the US weighted exchange rate. Koutsoyiannis (1983) found the price of gold to strongly related to a number of variables including the state of the US economy and the strength of the US dollar, Kaufmann and Winters (1989) also reported that the price of gold was based on changes in the dollar exchange rate.

4. Methodology

Many financial times series exhibit periods of low volatility followed by periods of high volatility known as volatility clustering. Autoregressive conditional heteroskedasticity (ARCH) was developed (Engle, 2001) in order to model and forecast the variance of financial and economic time series over time. ARCH models have been generalized to become the generalized ARCH or GARCH models. ARCH and GARCH models have become common tools for dealing with time series heteroskedastic models; these models provide a volatility measure that can be utilized in portfolio selection, risk analysis and derivative pricing.

A GARCH (1,1) model is very common in financial time series data, but ARCH and GARCH models have been expended over the previous two decades to factor in the direction of returns, not just the magnitude (Engle, 2001). They include, for example, the IGARCH model which allows for volatility shocks to be permanent, the TARCH (threshold ARCH) and the EGARCH (exponential GARCH) which are asymmetric models that allow negative shocks to behave differently from positive shocks. An EGARCH overcomes the problem of the standard ARCH/GARCH models where symmetry is imposed on the conditional variance.

Ding et al. (1993) introduced a new variant called the power ARCH (PARCH) model. In this addition to the ARCH family, the power term is estimated within the model rather than being imposed by the author. The advantage is that “rather than imposing a structure on the data, the PARCH model allows a power transformation term inclusive of any positive value and so permits a virtually infinite range of transformations” (McKenzie et al., 2001).

The power term is the means by which the data are transformed. The power term captures volatility clustering by changing the influence of the outliers. Traditionally data transformations
involved the use of a squared term. However, when the data is non-normally distributed, or where it is not otherwise possible to characterize the distribution by the mean and variance, the use of a squared power transformation is not appropriate and other power transformations are required in order to use higher moments to adequately describe the distribution. McKenzie asserts that when data is non-normally distributed, the use of a squared power transformation “imposes a structure on the data which may potentially furnish sub-optimal modeling and forecasting performance relative to other power terms” McKenzie and Mitchell (1999).

According to Brooks et al. (2000) the use of a squared power term is not always necessary or desirable. The author reports that the Taylor class of ARCH models stipulates a power term of one; in which case the conditional standard deviation of a series is related to lagged absolute residuals and past standard deviation, instead of the traditional use of lagged squared residuals. Brooks et al. (2000, p. 378) puts forward that any positive power term value can be specified as “absolute changes in an asset’s price will exhibit volatility clustering and the inclusion of a power term acts so as to emphasizes the periods of relative tranquillity and volatility by magnifying the outliers”. McKenzie and Mitchell (1999) highlights that volatility clustering is not just specific to the use of squared asset returns but are also a component of absolute returns. The use of a power term in these cases acts to emphasis the periods of tranquility and volatility by amplifying the outliers in the dataset.

A number of standard ARCH and GARCH models are nested within the asymmetric power GARCH model. The mean equation for each model where the model exhibits significant first order autocorrelation, an AR(1) specification is adopted.

In general, the APGARCH formulation can be given with $X$ representing additional explanatory variables hypothesised to effect the mean or variance

$$R_t = \alpha + \beta_i \sum R_{t-i} + \gamma_i \sum e_{t-i} + \psi_i \sum X + e_t$$

$$e_t \sim N(0, \sigma_t^d)$$

$$\sigma_t^d = c + \sum_{j=1}^{q} \beta_i \sigma_{t-j} + \sum_{i=1}^{p} \theta_i (|e_{t-i}| + \lambda e_{t-i})^d + \rho_i \sum X + \xi_t$$

Table 1 displays the various transformations and restrictions for each model nested with the APGARCH model. In essence, the restriction relates to the values of the ARCH and GARCH terms, the power term and the leverage effect term which vary according to the model required. The nested models include the standard ARCH and GARCH models, and other more exotic variants such as the leverage ARCH and GARCH models, the NARCH, TARCH, generalized TARCH, the Taylor ARCH and GARCH model, power GARCH, asymmetric power ARCH and GARCH models. By including a leverage term the standard ARCH and GARCH models become a leverage ARCH and GARCH. Similarly, the Taylor ARCH and GARCH models can be estimated by including a leverage term which creates the TARCH and generalized TARCH models. The ARCH, GARCH, Taylor ARCH and GARCH, NARCH and power GARCH all assume that volatility due to innovations in the market is symmetrical. We are aware that positive and negative returns of the same magnitude do not generate an equal response in volatility. Therefore, asymmetric ARCH and GARCH models are utilized to capture these stylized facts. A leverage ARCH, leverage GARCH, TARCH, generalized TARCH, asymmetric PARCH and an asymmetric power GARCH all incorporate a leverage effect term to account for asymmetric effects. A likelihood ratio test is used to ascertain the goodness of fit between the models.
Table 1
ARCH/GARCH model specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>(d)</th>
<th>(\theta)</th>
<th>(\beta)</th>
<th>(\lambda)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCH</td>
<td>2</td>
<td>Free</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GARCH</td>
<td>2</td>
<td>Free</td>
<td>Free</td>
<td>0</td>
</tr>
<tr>
<td>Leverage ARCH</td>
<td>2</td>
<td>Free</td>
<td>0</td>
<td>(\leq 1)</td>
</tr>
<tr>
<td>Leverage GARCH</td>
<td>2</td>
<td>Free</td>
<td>Free</td>
<td>(&lt;1)</td>
</tr>
<tr>
<td>Taylor ARCH</td>
<td>1</td>
<td>Free</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Taylor GARCH</td>
<td>1</td>
<td>Free</td>
<td>Free</td>
<td>(\leq 1)</td>
</tr>
<tr>
<td>TARCH</td>
<td>1</td>
<td>Free</td>
<td>0</td>
<td>(\leq 1)</td>
</tr>
<tr>
<td>Generalized TARCH</td>
<td>1</td>
<td>Free</td>
<td>Free</td>
<td>(\leq 1)</td>
</tr>
<tr>
<td>NARCH</td>
<td>Free</td>
<td>Free</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Power GARCH</td>
<td>Free</td>
<td>Free</td>
<td>Free</td>
<td>0</td>
</tr>
<tr>
<td>Asymmetric PARCH</td>
<td>Free</td>
<td>Free</td>
<td>0</td>
<td>(\leq 1)</td>
</tr>
<tr>
<td>Asymmetric PGARCH</td>
<td>Free</td>
<td>Free</td>
<td>Free</td>
<td>(\leq 1)</td>
</tr>
</tbody>
</table>

Table shows how by varying the elements noted in the system, \(R_t = \alpha + \beta \sum R_{t-i} + \gamma \sum e_{t-i} + \psi \sum X + e_t; e_t \sim N(0, \sigma^d_t); \sigma^d_t = c + \sum_{j=1}^q \beta_j \sigma^d_{t-j} + \sum_{i=1}^p \theta_i (|e_{t-i}| + \lambda e_{t-i})^d + \rho \sum X + \xi_t\) a variety of models are nested.

The applicability of the power ARCH model has been explored in various papers beginning with Ding et al. (1993), and following on with Hentschel (1995), McKenzie and Mitchell (1999), Brooks et al. (2000), Tooma and Sourial (2004) and Giot and Laurent (2004). These papers have documented the applicability of the PARCH model to stock market data. McKenzie et al. (2001) examined the applicability of the PARCH model to futures contracts traded on the London metal exchange (LME). The authors found that asymmetric effects were not present in the LME futures data and the APGARCH model did not provide an adequate description of the data. A Taylor GARCH was the preferred model. Brooks et al. (2000) makes use of the methodology proposed by Ding et al. (1993) and assesses the applicability of the power ARCH models to stock market returns in 10 countries and also the Morgan Stanley Capital International (MSCI) world index. The author reports that a significant leverage effect exists in national stock markets data. The power ARCH model and variant of the ARCH family is deemed the best fit for the data, taking into account GARCH and leverage effects. With the exception of the Singapore index, the power term optimally estimated was similar across all countries.

Ding et al. (1993) themselves examined S&P 500 stock market returns using the asymmetric power GARCH model to assess the impact of power transformations. The authors report a power transformation of 1.43 as the optimal transformation. McKenzie et al. (2001) reports that asymmetric effects are generally not present in the data and an asymmetric power GARCH model does not adequately describe the data, suggesting instead that a Taylor GARCH model is the optimal model for assessing these commodity futures, where the power term is unity. Tooma and Sourial (2004) examines the effect of changes in the microstructure of the Egyptian equity market using power ARCH models.

McKenzie and Mitchell (1999) similarly assess the applicability of the power ARCH models to exchange rate volatility where, according to the authors, asymmetry characteristics are not generally prevalent. In their analysis of 17 bi-lateral exchange rate return series, asymmetry was not evident in 12 of the currencies under examination. In this case, the standard GARCH (1,1) was the preferred model, while the inclusion of the power and/or leverage effect term did little to augment the model.
For the remaining five currencies, the inclusion of a leverage effect term was a beneficial inclusion, solely when the power term was estimated within the model. Tse and Tsui (1997) examine the conditional volatility of the Malaysian ringgit–US dollar and Singapore dollar–US dollar exchange rate data. The APGARCH model adequately modeled the data and the authors report that while asymmetry was evident in the Malaysian ringgit, it was not evident in the Singapore dollar. In this paper we use the full APGARCH specification, both for maximum flexibility and also as it was selected as the most appropriate model for the data.¹

4.1. Data

The data consists of monthly observations of gold, both cash and futures prices, and a set of macroeconomic variables, over the 1984–2003 period. All data are analysed in monthly percentage changes. The data analysed in this paper were sourced from DataStream. Data analysed include the daily gold bullion $/troy ounce rate, COMEX gold futures 100 oz rate, dollar and Pound Sterling effective exchange rate, FTSE 100 price index (FTSE cash), Brent Crude Oil Price $/barrel, S&P 500 and FTSE 100 equity indices in both cash and continuous futures form, UK and US CPI, unemployment, interest (T-bill) and industrial production indices. Based on previous research (Lucey and Tully, 2006) neither AR nor MA terms are included in the mean equation of the gold returns.

From previous V AR analysis² of this dataset a number of significant variables were identified that had an important influence on the price of cash and futures gold. From this VAR analysis the following variables were identified as influencing the price of gold, both cash and futures: FTSE cash, dollar, pound and United States interest rates, UK consumer price index. As we are interested in examining the influence of these variables on both the mean and variance, we include all variables in both equations.

5. Results

5.1. Summary statistics

Table 2 displays summary statistics of the data. Very high kurtosis is evident in the data. Also displayed in the tables are the Jarque-Bera statistics of the equality of the distribution. The results for almost all variables reject the equality of the distribution, implying that the data are non-normal. This finding, which is typical of financial assets, is noted by Brooks et al. (2000) who comment that in that case imposition of a squared term is imposition of structure which may or may not be appropriate.

5.2. Results: 1983–2003

Shown in Table 3 are the estimated coefficients of the APGARCH model for the entire period. A number of points are of interest. First, in terms of the mean equation, we note the continued

¹ Details of this testing are available on request.
² Results of this analysis are omitted for brevity, but are of course available on request. Essentially we estimated a standard V AR, with two lags, of all variables. The variables selected were those that contributed, in a forecast error decomposition analysis over 12 periods, more than 1% to the total decomposition of either the future or cash gold series as appropriate.
dominance of the dollar as an influence. Both in terms of their absolute and statistical significance the dollar is the largest influence. It is also negative, confirming again the long-held relationship of gold as an ‘anti-dollar’. In contrast to this we note that there appears to be no statistical relationship between interest rates or inflation and gold. Although these coefficients are negative (apart form inflation in futures gold) they are very insignificant. In terms of a tradeoff relative to equities, the relationship between gold and values of the FTSE is negative but insignificantly so, indicating a tradeoff. Of more interest is the relationship between the variables as they influence the variance of gold returns. Here it appears that apart from the structural elements of the GARCH equation no other variables influence the variance of gold. In effect, over the longterm, the volatility of the return on gold is determined endogenously, while the mean value of that return is somewhat influenced by the dollar.

Table 3
APGARCH estimates 1983–2003

<table>
<thead>
<tr>
<th></th>
<th>Gold cash</th>
<th>Gold future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean equation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.0007</td>
<td>0.0002</td>
</tr>
<tr>
<td>FTSE100</td>
<td>−0.0339</td>
<td>−0.0165</td>
</tr>
<tr>
<td>Dollar</td>
<td>−0.5075</td>
<td>−0.5885</td>
</tr>
<tr>
<td>Pound</td>
<td>0.0827</td>
<td>0.0359</td>
</tr>
<tr>
<td>US interest rates</td>
<td>−0.0181</td>
<td>−0.0184</td>
</tr>
<tr>
<td>UK CPI</td>
<td>−0.2736</td>
<td>0.0361</td>
</tr>
<tr>
<td>Variance equation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.0009</td>
<td>0.0007</td>
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<tr>
<td>Theta</td>
<td>0.0047</td>
<td>0.0377</td>
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<td>Lambda</td>
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<td>0.4930</td>
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<tr>
<td>D</td>
<td>1.8971</td>
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<tr>
<td>FTSE100</td>
<td>−0.0079</td>
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<td>Dollar</td>
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<tr>
<td>Pound</td>
<td>0.0052</td>
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<td>US interest rates</td>
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<tr>
<td>UK CPI</td>
<td>−0.0184</td>
<td>0.0246</td>
</tr>
</tbody>
</table>
5.3. Results: crisis periods

We also examine the relationships in two crisis periods for the equity markets. We first examine a two year window around the October 1987 crash, and second a two year window around the peaking of the bull market in March 2001. These analyses are shown in Table 4. We first note that again there are very few significance levels below 10%. The dominant role of the dollar is also evident. However, around the crisis periods we note that for cash gold in 1987 the magnitude and significance of the dollar coefficient is decreased. For 2000 the situation is more complex, the dollar losing further significance but increasing in magnitude. The futures markets show similar results, the 1987 dataset having lower dollar coefficients and the 2001 greater. In both cases however the significance levels are still under 10%.

6. Conclusion

Utilising the methodology of Ding et al. (1993) and Brooks et al. (2000) this paper has examined the fit of the APGARCH model for six gold models. This analysis concludes that an APGARCH model is applicable to the datasets in question, taking into account GARCH, leverage and power effects. Using gold cash and futures data over a long period we confirm that the US dollar is the main, indeed in many cases the sole, macroeconomic variable which influences gold.

References